

What is claimed is:

1. A method, comprising:

interrogating a process stream with ultrasound by pulsing a focused sound field of ultrasound into the process stream,

receiving an off-angle ultrasound scattering response to the interrogating with a plurality of detectors at spaced location; and

determining presence of foreign material in the process stream if the off-angle ultrasound scattering response exceeds a predetermined threshold.

2. The method of claim 1 wherein the process stream is interrogated with ultrasound from an ultrasound transmitter aligned along an interrogation axis and wherein the received ultrasound response scatters at an angle of greater than 10 degrees from the interrogation axis.

3. The method of claim 2 wherein the received ultrasound response scatters at an angle of between about 10 and about 45 degrees from the interrogation axis.

4. The method of claim 2 further comprising determining the spatial location of the foreign material in the process stream based on the response from detectors focused on different portions of the process stream.

5. The method of claim 4 wherein the scattering response is received by at least one ultrasound receiver aligned along a detection axis non-parallel to the interrogation axis and the angle between the interrogation and detection axes is between about 15 and about 25 degrees.

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6. The method of claim 1 wherein the process stream is heterogeneous and the foreign material is contained in the heterogeneous process stream, and wherein the predetermined threshold is selected to exceed the off-angle scattering response attributable to scattering targets of the bulk heterogeneous process stream.

7. The method of claim 1 wherein the process stream is interrogated with ultrasound at a frequency of between about 0.1 and 5MHz in air.

8. The method of claim 1 wherein the process stream is interrogated with ultrasound with a wavelength in the process stream and the detected foreign material has a length dimension, and wherein the length dimension divided by the wavelength is greater than about one.

9. The method of claim 1 further comprising operating a diverter to select a diversion channel for at least a portion of the process stream when presence of foreign material is determined.

10. The method of claim 1 wherein the process stream is contained in a conduit having at least one flat wall and the process stream is interrogated with ultrasound through the flat wall.

11. The method of claim 10 wherein the plurality of detectors receive the off-angle scattering response through the flat wall.

12. The method of claim 11 wherein the conduit defines a flow path with a generally rectangular cross section adjacent the detectors.

13. The method of claim 1 wherein the process stream is contained in a conduit defined by at least one wall and the interrogating ultrasound and the received off-angle scattered ultrasound pass through a solid acoustic coupling in contact with the at least one wall.

14. The method of claim 1 further comprising comparing the response from the plurality of receivers to associated predetermined thresholds,

wherein the presence of an foreign material in the process stream is determined when the received off-angle ultrasound scattering response for more than one of the plurality of receivers exceeds the associated predetermined thresholds.

15. A system, comprising:

a conveyor operable to provide a process stream;

one or more inspection devices operable to transmit pulses of focused ultrasound to interrogate the process stream and receive an off-angle ultrasound scattering response to interrogation with the ultrasound; and

a processing device operable to determine presence of a foreign material in the process stream based on a comparison of the off-angle ultrasound scattering response to a predetermined threshold;

wherein the inspection devices include a plurality of spaced receivers each operable to receive an off-angle ultrasound scattering response to interrogation with ultrasound from a common transmitter.

16. The system of claim 15 wherein the processing device is operable to compare the received scattering response from each of the receivers to predetermined associated thresholds.

17. The system of claim 15 wherein the receivers are focused on different portions of the process stream and the processing device is operable to provide an indication of the spatial location of the foreign material in the process stream.

18. The system of claim 15 wherein the processing device is operable to compare the received scattering response from each of the receivers to associated predetermined background response levels.

19. The system of claim 15 wherein the interrogation devices include an ultrasound transmitter operable to deliver a cylindrically focused sound field to the process stream with the focal line generally perpendicular to the flow direction of the process stream.

20. The system of claim 19 wherein the plurality of receivers are positioned in a line generally parallel to the focal line of the cylindrically focused sound field.

21. The system of claim 15 wherein the process stream has at least first and second paths downstream from the one or more inspection devices, the system further comprising a diverter operable to cause at least a portion of the process stream to travel down the second path when the presence of an foreign object in the process stream is determined.

22. The system of claim 15 wherein the process stream is contained in a conduit having at least one flat wall and the process stream is interrogated with ultrasound through the flat wall.

23. The system of claim 22 wherein the plurality of detectors receive the off-angle scattering response through the flat wall.

24. The system of claim 23 wherein the conduit defines a generally rectangular cross section.

25. The system of claim 15 wherein the process stream is contained in a conduit defined by at least one wall and the interrogating ultrasound and the received off-angle scattering response pass through a solid acoustic coupling in contact with the at least one wall.

26. The system of claim 25 wherein the solid acoustic couplant is a wedge piece defining a face parallel to the bulk material flow direction for receiving an inspection device for transmitting acoustic pulses and a pair of faces not parallel to the flow direction for receiving inspection devices for receiving the scattering response.

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27. A method, comprising:
interrogating a stream of foodstuff with ultrasound;
detecting an off-angle ultrasound scattering response to said interrogating with a plurality of spaced ultrasound receivers; and
determining if foreign material is present in the foodstuff based on the off-angle ultrasound scattering response.

28. The method of claim 27 wherein the foodstuff is meat and the foreign material is bone.

29. The method of claim 27 wherein the interrogation includes pulsing a focused sound field of ultrasound into the process stream, the focused sound field spanning a majority of the cross section of the process stream such that a majority of the material in the process stream can pass through the focused sound field.

30. The method of claim 29 wherein the plurality of receivers include at least two receivers focused on overlapping volumes.

31. The method of claim 29 wherein the plurality of receivers include at least two receivers focused on substantially non-overlapping volumes.

32. The method of claim 31 wherein the plurality of receivers include at least two receivers focused on overlapping volumes.

33. The method of claim 32 further comprising operating a diverter downstream from the receivers to selectively divert a portion of the stream of foodstuff.

34. The method of claim 29 wherein the foodstuff is interrogated with ultrasound from an ultrasound transmitter aligned along an interrogation axis and wherein the received ultrasound response scatters at an angle of between about 10 and 35 degrees from the interrogation axis.

35. A system comprising:

a conduit having at least one flat wall operable to receive a process stream,
one or more inspection devices operable to transmit ultrasound through the flat wall to interrogate the process stream,
a plurality of spaced receivers each operable to receive an off-angle ultrasound scattering response to interrogation with the ultrasound; and
a processing device operable to determine presence of a foreign material in the process stream based on a comparison of the off-angle ultrasound scattering response to a predetermined threshold.

36. The system of claim 35 wherein the plurality of receivers are operable to receive the off-angle ultrasound scattering response through the flat wall.

37. The system of claim 35 wherein the one or more inspection devices includes a cylindrically focused ultrasound transmitter.

38. The system of claim 37 wherein the conduit defines a bulk flow direction adjacent the inspection devices and the focal line of the transmitter is substantially perpendicular to the bulk flow direction.

39. The system of claim 35 wherein the conduit defines a flow path with a generally rectangular cross section adjacent the inspection devices.

40. The system of claim 35 further comprising a process stream of foodstuff in the flow path.

41. A system comprising:

a conduit defining a flow path with a generally rectangular cross section,

one or more inspection devices operable to transmit ultrasound to interrogate a process stream in the generally rectangular portion of the flow path,

a plurality of spaced receivers each operable to receive an off-angle ultrasound scattering response to interrogation with the ultrasound; and

a processing device operable to determine presence of a foreign material in the process stream based on a comparison of the off-angle ultrasound scattering response to a predetermined threshold.

42. The system of claim 41 wherein the one or more inspection devices are operable to transmit pulses of focused ultrasound into the flow path.

43. The system of claim 41 wherein the plurality of receivers include at least two receivers focused on overlapping volumes.

44. The system of claim 41 wherein the plurality of receivers include at least two receivers focused on substantially non-overlapping volumes and the processing device is operable to provide an indication of the spatial location of the foreign material in the process stream.

45. The system of claim 44 wherein the plurality of receivers include at least two receivers focused on overlapping volumes.

46. The system of claim 45 wherein solid material forms a majority of the acoustic path between the inspection device and the process stream and between the process stream and the receivers.

47. The system of claim 45 wherein the solid material defines a face parallel to the bulk material flow direction in contact with the inspection device and a pair of faces not parallel to the flow direction in contact with the receivers.

48. The system of claim 45 wherein the solid material is integral with the conduit.

49. A system comprising:
a conduit operable to receive a process stream,

one or more inspection devices operable to interrogate a volume of material in the process stream with ultrasound,

at least two receivers focused on substantially non-overlapping interrogated volumes of material each operable to receive an off-angle ultrasound scattering response to the interrogation; and

a processing device operable to determine presence of a foreign material in the process stream and to provide an indication of the spatial location of the foreign material in the process stream based on a comparison of the off-angle ultrasound scattering response of each receiver to a predetermined threshold.

50. The system of claim 49 wherein the one or more inspection devices are operable to transmit pulses of focused ultrasound into the flow path.

51. The system of claim 49 wherein the plurality of receivers include at least two receivers focused on overlapping volumes.

52. The system of claim 49 wherein solid material forms a majority of the acoustic path between the inspection device and the process stream and between the process stream and the receivers.

53. The system of claim 52 wherein the solid material defines a face parallel to the bulk material flow direction in contact with the inspection device and a pair of faces not parallel to the flow direction in contact with the receivers.

54. The system of claim 53 wherein the solid material is integral with the conduit.
55. The system of claim 26 wherein the wedge piece and the at least one wall are integral.
56. The method of claim 1 further comprising:
capturing an image of the process stream while optically backlighting the process stream;
determining presence of foreign material in the process stream if at least a portion of the
captured image exceeds a predetermined threshold.
57. The method of claim 28 further comprising:
capturing an image of the foodstuff stream while optically backlighting the stream;
determining presence of bone in meat if at least a portion of the captured image exceeds a
predetermined threshold.
58. The method of claim 57 wherein the captured image includes light in the range of between
about 500 and about 600nm.

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